Nest site fidelity of Flatback Turtles (*Natator depressus*) on Bare Sand Island, Northern Territory, Australia

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Abstract

The endangered Flatback Turtle (*Natator depressus*) is endemic to the continental shelf of northern Australia and is the only species of marine turtle with such a restricted geographical distribution. Most mature female Flatback Turtles show a high degree of fidelity to their chosen nesting beach, returning to the same beach within the same and successive nesting seasons. Natal homing has been well studied in other species of marine turtles and our findings support the supposition that *all* marine turtles display a similar degree of natal homing. Our study area is Bare Sand Island, Northern Territory, where we investigated nest site fidelity of female Flatback Turtles and the influence of wind speed, air and sand temperature, and relative humidity on nest site selection. The data were collected during a 46-day period from 12 June 2012. On Bare Sand Island, female Flatback Turtles demonstrate very strong nest site fidelity, with consecutive nests being located 247 m ± 198 s.d. apart. During the peak 2012 breeding season, sand temperatures, wind speed and relative humidity remained constant, however there was a significant difference in the air temperature between nesting days. Our study of the effects of environmental factors on the nesting environment of Flatback Turtles will contribute towards management practices to protect this endangered species.

Introduction

The range of the Flatback Turtle (*Natator depressus*) is limited to the continental shelf of northern Australia and its distribution is the most geographically restricted of all marine turtle species (Limpus 2009). Unlike other marine turtles, Flatbacks lack an oceanic phase in their life cycle and remain in the surface waters of the continental shelf (Walker & Parmenter 1990). They are identified by four pairs of costal scales on a low-domed carapace and a pair of prefrontal scales on the head. The carapace of the hatchling measures approx. 6 cm and weighs approx. 43 g. At maturity, the adult female Flatback Turtle is olive grey, has an average carapace length of 92 cm and weighs around 90 kg (Limpus 2009). Flatback Turtles come ashore to lay their eggs on remote beaches along the tropical and subtropical northern Australian coastline (Whiting *et al.* 2008).

As a consequence of the destruction of nesting habitats and fishing bycatch, the *Environmental Protection of Biodiversity and Conservation (EPBC) Act (1999)* has classified the Flatback Turtle as Endangered. The Flatback is the only marine turtle that the International Union for Conservation of Nature lists globally as Data Deficient (IUCN 2010). Marine turtles are becoming increasingly threatened as a result of commercial fishing bycatch, boat strike, illegal harvesting of eggs and adults, and an increase in nesting habitat destruction (Limpus 1995; Whiting & Guinea 2003). Of all the species of marine turtles, the Flatback is by far the most under-researched and under-reported (Pendoley *et al.* 2014).

It has been suggested that the breeding site selection of marine turtles may be attributed to individual animals imprinting on magnetic fields in their natal area and then, years later, using this information to return to their natal site (Hueter 1998; Lohmann *et al.* 2008). However, uncertainty remains as to whether their homing is attributable to imprinting to the natal beach as a hatchling, or imprinting to the region of their birth and then the specific beach as an adult during their first breeding season (Limpus 2009).

Genetic analyses show that the precision of natal homing can vary considerably among different populations and species with homing to regions of coastline measuring several hundred kilometres being common (Lohmann *et al.* 2008). Female Flatback Turtles generally lay three to four clutches of eggs each nesting season with an inter-nesting interval of approx. 14 days (Hewavisenthi & Parmenter, 2002). Mature female Flatback Turtles show a high degree of fidelity to their nesting place, returning to the same beach to lay consecutive clutches within a nesting season and in successive nesting seasons (Limpus 2009; Oates 2010; Matos *et al.* 2012).

The environment of the nest site is important for marine turtles because it influences offspring sex, embryonic survival, hatchling development rates and hatchling size, mass and energy reserves (Hewavisenthi & Parmenter 2002; Koch *et al.* 2007). To date, however, there is little understanding of the physical factors that contribute to the distribution of turtle nesting (Santana Garcon *et al.* 2010). What *is* known, is that sex determination is temperature-dependent; higher temperatures produce females, whilst lower temperatures result in male hatchlings (Santana Garcon *et al.* 2010; Hewavisenthi & Parmenter 2002).

The northern tropical Australian populations of Flatback Turtles have a protracted nesting period of around nine months of the year, reaching a peak in July (Whiting *et al.* 2008). Several studies have attempted to examine the influence of beach characteristics on nesting cycles (Parmenter & Limpus 1995; Hewavisenthi & Parmenter 2002; Koch *et al.* 2007; Whiting *et al.* 2008). In this study we investigated nest site fidelity of female Flatback Turtles on Bare Sand Island within a single breeding season to assess the influence of environmental factors on nest site selection. The study site was free of introduced predatory species and human interference was minimal. The environmental factors considered were wind strength, relative humidity, and air and sand temperatures.

Fig. 1. Location of nest sites where female Flatback Turtles laid more than once during the 2012 peak breeding season on Bare Sand Island, Northern Territory. (Courtesy Digital Globe 2012)

Materials and Methods

Our study site is Bare Sand Island (12°32.39'S, 130°25.02'E), which is 50 km west of Darwin, Northern Territory. It is located towards the end of a chain of eight islands (Whiting & Guinea 2003; Koch & Guinea 2006). The main nesting beach faces west and is composed of fine sand with a gentle rise, making the nesting beach easily accessible from the ocean (Koch & Guinea 2006). The data were collected during a six and a half week period from 12 June 2012.

Two-hour foot patrols either side of the evening high tide were undertaken to coincide with the turtles' main nesting activity. Turtles were identified by their tags or were tagged on-site and the nest location was recorded using Garmin GPSmap 60CSx, or Garmin GPS72, or Garmin GPS72H. GPS points, and their corresponding tags, were uploaded into ESRI ArcMap 10.1 (© 2012, ESRI, Redlands, California) and a Microsoft® transposed onto a Google Earth Image Landsat© 2012 Google using the Landsat 7 Satellite (see Fig. 1). The image was geo-referenced against known latitude and longitude co-ordinates and projected into the WGS 84 Global Positioning System with our accuracy of approximately 5 m. A Hobo™ water temp Pro v2 data logger was buried in the sand on top of a dune at the same depth as that of a Flatback Turtle's nest (50 cm) and another was positioned in the middle of the western beach. The sand temperature was recorded every half hour and air temperatures and wind speeds were recorded daily at 18.45 hr using a hand-held Air™ speed temperature meter (Dick Smith Qf301). The meteorological data were compared with readings from the Australian Bureau of Meteorology weather station (AWS Station 014277) located on Dum In Mirrie Island (13 km south of Bare Sand Island) and we were satisfied that the Meteorological Station data were suitable for our study purposes.

For each female, the distance between consecutive nests during the 2012 season was calculated using ArcMap on-board measuring toolsets. These distances were compared with those from previous nest sites to an equal number of randomly generated potential nest sites and a two sample *t*-test was used to determine whether the two samples were significantly different. To determine whether there were differences between environmental conditions, paired *t*-tests were used to compare the environmental data from the different days when female Flatbacks nested. Both the paired and *t*-tests were analysed using alpha values of 0.05. All the data were analysed using Microsoft Excel 2010 (© 2010 Microsoft Corporation, Redmond, Washington, U.S.A) and Minitab 15 (© 2007 Minitab Inc., State College, Pennsylvania, U.S.A.).

Results

Fifty-four female Flatback Turtles were observed coming onto Bare Sand Island to nest more than once. Of these, four returned three times, two nested four times and the rest nested twice. The mean inter-nesting period was 19 days ± 1.58 s.d. with the minimum and maximum inter-nesting periods being 15 days and 37 days, respectively. The locations of nest sites for females that nested more than once on Bare Sand Island are shown in Fig. 1.

The mean individual inter-nesting distance was 247 m ± 198 s.d. with a minimum of 7 and a maximum 687 m. We found that more than 50% of the females laid their second nest within 250 metres of their initial nesting site and that they were non-randomly selected ($t = -4.79$; $P = 0.000$; *d.f.* = 108). The mean distance between two nest sites of the same female was 247 m ± 198 s.d., whereas the mean distance between randomly selected sites is 456 m ± 277 s.d.. The mean air temperature on Bare Sand Island was 24.35°C ± 1.25 s.d. and was not significantly different from the meteorological recordings on Dum In Mirrie Island ($t = -0.89$; $P = 0.376$; *d.f.* = 52). The same was true for wind speeds, with a Bare Sand Island mean of 10.09 km/h ± 5.0 s.d.($t = 0.36$; $P = 0.718$; *d.f.* = 42).

The mean wind speed was 9.75 km/h ± 2.60 s.d. and the mean relative humidity was 52.1% ± 19.0. The effects of four environmental elements on nesting behaviour were studied; namely, air and sand temperatures, wind speed and relative humidity. The mean values of the four sets of data were recorded on days when the same female turtle nested and were compared to determine whether they differed significantly (see Table 2). Using paired *t*-tests, we found no significant difference between the sand temperature, wind speed or relative humidity on different nesting days, however there was a difference in air temperatures.

Table 2. Comparison of environmental factors influencing nest site conditions of the same female turtle on consecutive nesting times.

	Mean Nest 1	Mean Nest 2	*t*- Value	*P*- Value
Sand temperature	28.16 ± 0.46 °C	28.17 ± 0.48 °C	-0.06	0.950
Wind speed	9.98 ± 2.55 km/h	10.23 ± 2.48 km/h	-0.52	0.608
Relative humidity	43.07 ± 15.50%	45.25 ± 18.07%	-0.69	0.494
Air temperature	24.72 ± 1.41 °C	25.47 ± 1.44 °C	-2.57	0.013

Discussion

The number of Flatback Turtles that returned to Bare Sand Island to nest during the 2012 breeding season was lower than in previous years – a fact that may be attributed to it being the coldest July in 35 years (Australian Government Bureau of Meteorology 2012). The nesting rates of the turtles observed in our study were generally less than the 3–4 clutches expected for Flatback Turtles during a nesting season (Hewavisenthi & Parmenter 2002), however, our data collection period was limited to the peak nesting period. The inter-nesting period we recorded was 19 days ± 1.58 s.d. This is longer than the mean 15-day inter-nesting interval that usually occurs with Flatback Turtles within the same season (Limpus *et al.* 1984; Hewavisenthi & Parmenter 2002). Again, this might be attributed to the cooler water temperatures that are known to reduce the rate of pre-ovipositional development of eggs during inter-nesting for Loggerhead, Olive Ridley and Green Turtles (Sato *et al.* 1998; Hays *et al.* 2002; Matos *et al.* 2012).

From Figure 1 it can be seen that the study animals preferentially nested on the western beach on Bare Sand Island. This is consistent with previous years and is attributed to the fine sand and the gently sloping beach that faces the open ocean (Koch & Guinea 2006). Although it is not entirely clear why some beaches are preferentially selected by sea turtles to deposit eggs, a number of factors have been identified. The beach must be easily accessible from the ocean, be high enough to avoid inundation at high tide and have temperatures conducive to egg development (Miller *et al.* 2003). The south-easterly section of the island is exposed to strong trade winds throughout the nesting season which explains its low nest density (Koch & Guinea 2006; Koch 2007).

The high degree of nest site fidelity observed in our study animals agrees with the similar findings of Limpus (2009), Oates (2010) and Matos *et al.* (2012). Our study suggests that Flatback eggs may be more tolerant of higher incubation temperatures than those of most other sea turtle species; a finding that is supported by the work of Hewavisenthi & Parmenter (2002). This change in air temperature may have contributed to the females' nest site choice, as the nesting phase of the marine turtles' reproductive cycle is thought to be largely determined by temperature (Santana Garcon *et al.* 2010). Higher temperatures will reduce the turtles' progress across a beach to the ocean. However, as they typically emerge at night, their movements are not hindered by high temperatures (Koch *et al.* 2008). The mean inter-nesting distance of 247 ± 198 m for Flatback Turtles differs markedly from Olive Ridley Turtles (4.83 ± 4.37 km) and Green Turtles (0–5 km) (Matos *et al.* 2012; Lalith Ekanayake *et al.* 2003).

Sand temperature, however, plays a vital role in the development of turtles and influences hatchling size, sex, and energy reserves and successful incubation is only possible within certain thermal limits. Nest temperatures are variable not only on a single beach within a season and at different levels on the shore, but also vary with depth at a single nest site (deeper eggs are incubated at rather lower, more stable temperatures). The influence of short periods of extreme temperature is unclear. However, it has been reported that the final third of the incubation period is particularly temperature-sensitive and eggs rarely hatch if exposed to temperatures below 23°C or above 33°C (Davenport 1997). Flatback Turtles appear to be more tolerant of high incubation temperatures and severe moisture stress than most marine turtle species (Hewavisenthi & Parmenter, 2002).

Sand temperature influences the timing of the emergence of Flatback hatchlings. Most left the nest during the same few hours each night because of thermal cues that are dependent upon a combination of threshold temperatures, thermal gradients in the nest, and rates of temperature change (Davenport 1997; Koch *et al.* 2008). As sand temperatures at the study site remained below 29.3°C (the pivotal temperature) and as sex determination is temperature-dependent, predominantly male hatchlings emerged (Koch *et al.* 2007).

Strong south-easterly seasonal trade winds have persisted throughout the nesting season on Bare Sand Island over the last 10 years and, while this has the potential to affect the depth of the nests, they were not reported to have been shallower than 20 cm and were not subsequently threatened by the high temperatures that occur late in the nesting season (Koch & Guinea 2006; Koch *et al.* 2007). We found no significant difference between the mean relative humidity (52.1% ± 19.0 s.d.) on successive nesting days. Favourable conditions for embryonic development and survival include high humidity influencing hatchling size, sex, and energy reserves (Hewavisenthi & Parmenter 2002; Miller *et al.* 2003).

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